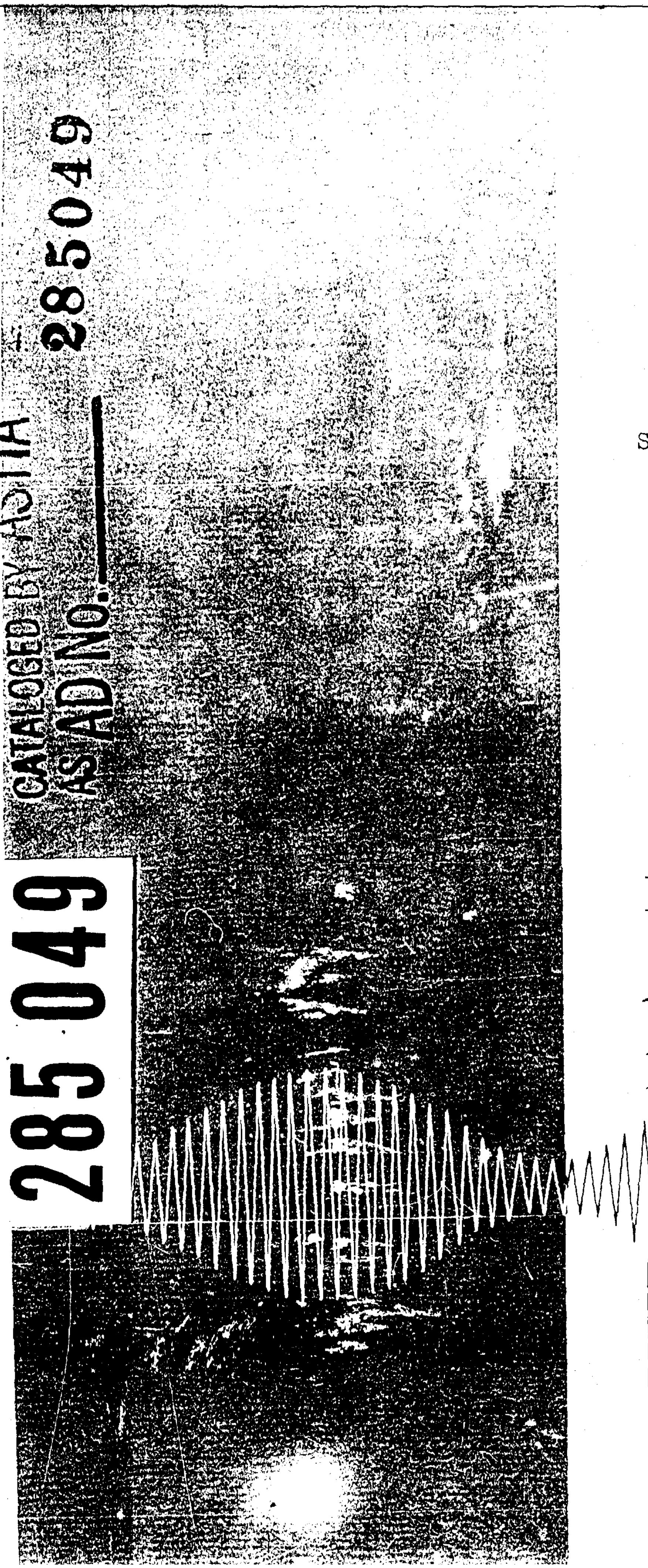

HIGH POWER CAPABILITIES

OF

WAVEGUIDE SYSTEMS

Sixth Quarterly Progress Report

May 1, 1962 to July 31, 1962

Contract NObsr - 85190

Index No. SR0080302, ST 9604

Department of the Navy
Bureau of Ships
Electronics Division

MICROWAVE ASSOCIATES, INC.

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## ABSTRACT

This report discusses further the concept and utility of the diffusion length. An example is given of its application to the solution for electric field strength at breakdown. Close to breakdown threshold, the diffusion length varies rapidly, further increasing the sensitivity of breakdown to pulse length. This is illustrated in terms of percent "over-voltage".

## LIST OF ILLUSTRATIONS

# PURPOSE

The purpose of this program is to study the various effects in waveguide systems which lead to failures at ultra-high power levels where high average as well as high peak power become limiting factors. Ultimately a handbook will be prepared to serve as a guide for system's engineers. To achieve the objectives of the program a survey is being made of organizations using ultra-high power; further analysis and theory is being carried out, and experiments are being performed.

# INTRODUCTION

In the previous reports, information has been presented for the revised handbook. One addition to the handbook will be the relationship of the diffusion length to breakdown under non-uniform field conditions. In the last report the use of the diffusion length was discussed.

One subject of the present report is that of obtaining the value of the electric field strength to pressure, E/p, when waveguide dimensions and pressure are given. The other subject of this report is a discussion of the influence of the non-uniformity of the field on breakdown near threshold under short pulse conditions. The diffusion length enters through its relationship to the non-uniformity of the field.

## DETAILED FACTUAL INFORMATION

### Component Testing

The high power measurements on components has been delayed by the lack of high power windows required to isolate the component under test. Part of the delay was also due to the need to shift the experiment to S band frequencies. Recently we have obtained several high power windows and expect to proceed with the measurements.

### Diffusion Lengths

The meaning and use of the diffusion length was briefly discussed in the previous progress report. In one type of problem discussed the ratio of electric field strength to pressure, E/p, is sought when the waveguide dimensions and pressure are given. Since the diffusion length is generally a function of the unknown quantity E/p (see Figure 1a) there is no direct method for ascertaining its value. Therefore as a first approximation the value of diffusion length is assumed to be that corresponding to a uniform electron production in the volume,

$$\Lambda_o^2 = \left[\left(\frac{\pi}{a}\right)^2 + \left(\frac{\pi}{b}\right)^2\right]^{-1}$$

for rectangular waveguide.

With this first approximation for $p\Lambda$, a value for E/p is obtained from the universal breakdown curve (see Figure 1b). With this value of E/p a new value of $\Lambda$ is obtained from Figure 1a. Now use this second value of $\Lambda$ to compute $p\Lambda$ for use in Figure 1b. Thus a second value is obtained for E/p. This procedure is repeated until E/p converges to a particular value. The initial value of E/p corresponds to that for breakdown under uniform field conditions. The final value of E/p is generally greater and accounts for the non-uniformity of the electric field.

The diffusion length is indicative of the rate of loss of electrons by diffusion. When the diffusion length is small, the rate of diffusion is generally large. Therefore, the smaller the diffusion length, the slower is the rate of build up of electron density; this means a longer time would be required for breakdown. Under short pulse conditions the rate of electron build up can be low enough so that breakdown will not occur. Under non-uniform field conditions, because the ionization region becomes small near threshold value of E/p, the diffusion length also becomes small near threshold (see Figure 2). This raises the value of E/p required for breakdown and may be referred to as "diffusion controlled" threshold. This is illustrated in Figure 3 by a plot of percent "over-voltage" [the threshold value of (E/p) equals 31.5 for air] for breakdown in rectangular waveguide as a function of $p\tau$ with pb as a parameter. It is convenient to present the information in terms of the normalized quantities E/p, pb, and $p\tau$. The effect of the uniformity of the field

is also shown for a particular value of pb. The breakdown field for the non-uniform case is seen to be larger than the uniform case (dashed curve in Figure 3). Under pulsed conditions close to threshold, the non-uniformity is seen to lead to a larger pulse length for breakdown than for the uniform case. The variation of $\Lambda$ with E/p is taken into account in the graph. Close to threshold or close to "diffusion controlled" threshold the pulse length also becomes very sensitive to amplitude variations. With reference to Figure 3, the pulse width for breakdown varies rapidly with percent over-voltage. The closer to threshold, the more rapid is the variation.

This discussion has pointed out that the non-uniformity in electric field in a waveguide contributes to a rapid variation in the pulse length required for breakdown near threshold.

Handbook Preparation

Additional graphs are being prepared for the handbook as has been described in the earlier reports.

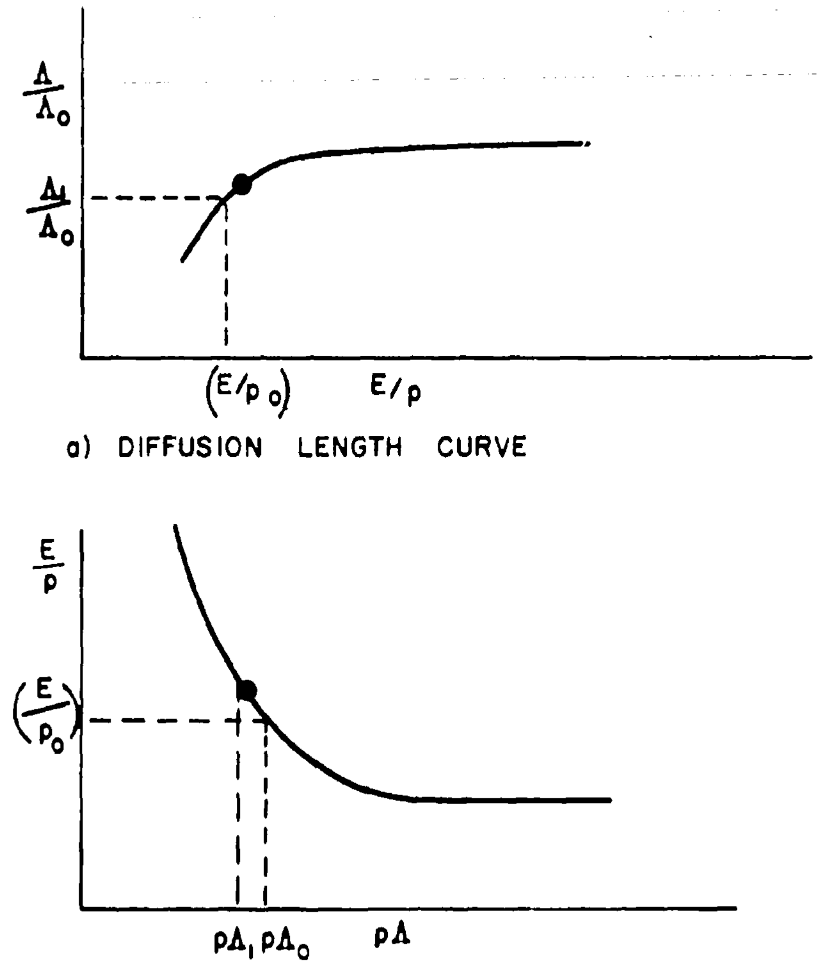
## CONCLUSIONS

By using the universal breakdown curve and a knowledge of the diffusion length the value of electric field strength can be determined. However, as the diffusion length is not known exactly for non-uniform conditions, a method of successive approximations is necessary for obtaining the value of E/p.

Under pulsed conditions the non-uniformity in electric field in a waveguide contributes to the rapid variation in pulse length required for breakdown near threshold. Thus the pulse length becomes larger under non-uniform conditions then for comparable uniform field cases.

PLANS FOR THE NEXT INTERVAL

In the next interval final cavity measurements over a wide range of pressures should be completed for air, $SF_6$ and Freon 12. Also, the testing of components will be carried out in S-band instead of C-band. The draft for the handbook will be prepared.



a) DIFFUSION LENGTH CURVE

b) UNIVERSAL BREAKDOWN CURVE

FIGURE I

GRAPHICAL SOLUTION OF NON-UNIFORM BREAKDOWN PROBLEM

FIGURE 2

DIFFUSION LENGTH
IN AIR FILLED RECTANGULAR WAVEGUIDE

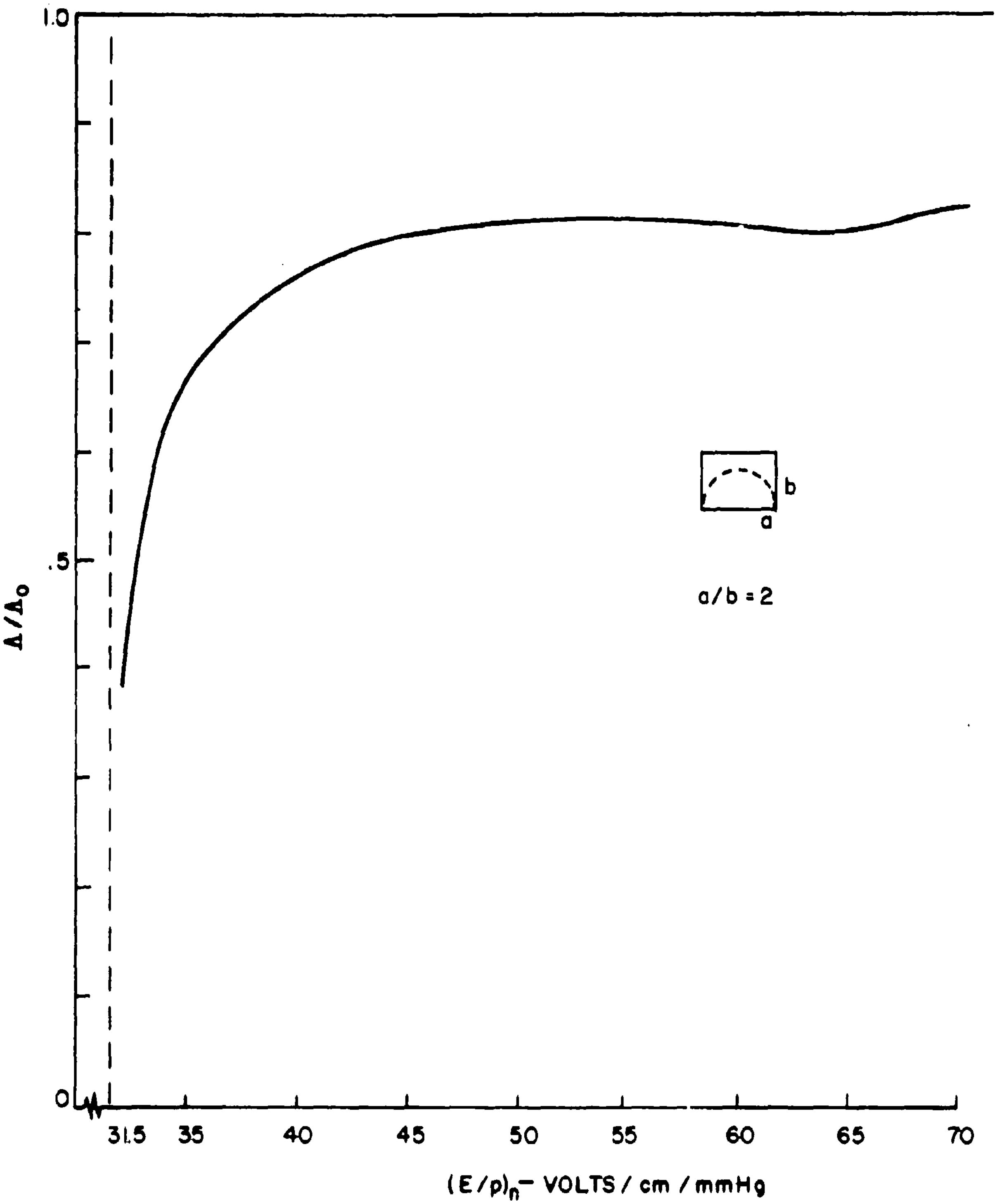
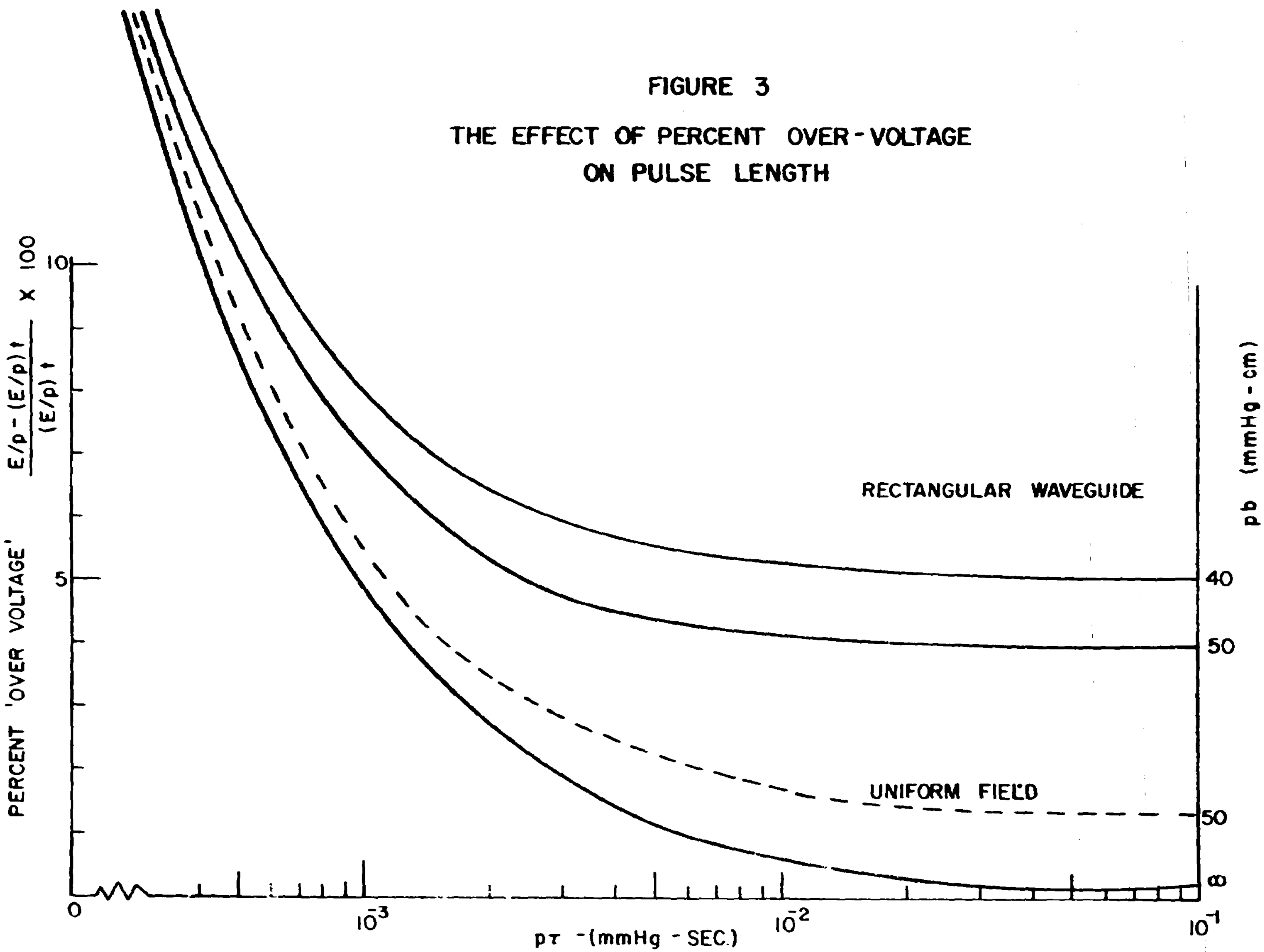


FIGURE 3

THE EFFECT OF PERCENT OVER-VOLTAGE ON PULSE LENGTH



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